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Articles

PAGE

The Relativity Deflection of Light - - - - *Charles Lane Poor* 225
Velocity and Light Curves of 12 Lacertae - *William H. Christie* 239
The Planet Saturn - - - - - - - - *W. G. Calgrove* 241

Notes and Queries

Sir Isaac Newton's Bi-Centenary - - - - - - - - 246

Meetings of the Society

At Victoria, 248; at London, 254; at Montreal - - - - - 255

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THE JOURNAL
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ROYAL ASTRONOMICAL SOCIETY
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VOL. XXI, No. 6 JULY-AUGUST, 1927 Whole No. 1 6

THE RELATIVITY DEFLECTION OF LIGHT[1]

By CHARLES LANE POOR

The claim of the relativists, which has attracted the greatest popular interest, is that of "bent light"; the claim that light has weight and falls towards the earth in a manner entirely similar to that of the famed apple of Newton. And this interest has been intensified by the widely heralded eclipse expeditions to Africa, to South America, and to Australia to test and to verify the predictions of Einstein, and by the repeated assertions that these expeditions have fully confirmed all the wonders of the relativity theory by obtaining results which "are in exact accord with the requirements of the Einstein Theory".

But just what these requirements of the theory really are, and how they result from the theory, neither Einstein, nor any of his followers, has explained in simple, understandable language. Einstein, himself, has given two very definite predictions as to the amount by which the light of a star should be bent, or deflected in its passage by the sun. In 1911 he fixed this amount as 0″.83; in 1916 he doubled this and made the deflection, according to his theories, 1″.70. But the way in which Einstein derived these two different values is not given in any general works on relativity. Such works of the relativists are replete with philosophical contemplations, with vague speculations and generalizations as to the structure of the universe, with references to the principle of

[1]Presented at the Philadelphia Meeting of the American Association for the Advancement of Science and the American Astronomical Society. December 29, 1926.

equivalence, to warps and twists in space; but they one and all fail to give a direct explanation of the basis of Einstein's claim as to the deflection of light rays, and of the ways in which he arrived at the two different and conflicting values. The statement of Einstein, contained in his general work on relativity, is probably as clear and definite as any that can be found, and that statement is:[2]

> "According to the theory half of this deflection is produced by the Newtonian field of attraction of the sun, and the other half by the geometrical modification ('curvature') of space caused by the sun."

If this be taken literally then it would appear that Einstein, in 1911, evolved the theory that light has weight and is acted upon by gravitation in exactly the same way as is a particle of matter; that he afterwards and prior to 1916 found that the sun warps and twists space in its neighborhood, and that light is further deflected by its passage through such warps and twists. Thus it would seem that his 1911 prediction of a deflection of only 0″.83 was based upon some direct effect of Newtonian gravitation upon light; that his revised prediction of 1″.70 in 1916 was based upon some additional and newly discovered effect of gravitation upon space. The summation of these two supposed effects of gravitation, the one directly upon a body, the other indirectly through an intermediary action upon space, has been termed a "new", or the "Einstein" law of gravitation. And the deflections of light, observed at solar eclipses, have been cited as tests between these two theories, or laws of gravitation:—the Newtonian and the Einsteinian.

The importance of finding out just how Einstein made these calculations is thus evident; for such calculations must indicate clearly the basis upon which depends his prediction of "'bent light", and the exact change in that basis, or additional assumption, which turned the computed 0″.83 of 1911 into the final 1″.70 of 1916. Fortunately these calculations are set forth in considerable detail in his original mathematical papers which form the basis of the relativity theory, and which were published in the "Annalen der Physik". This present paper is based upon the formulas and

[2] EINSTEIN: "Relativity: the Special and General Theory." Translated by R. W. Lawson, 1920. Appendix III, page 153.

computations contained in these basic documents of relativity, and is an attempt to explain just what Einstein's theory as applied to light really is, and how and why his predictions differ.

Einstein's researches as to gravitational fields and the possible effects of gravitation upon the physical conditions of bodies and upon light, were purely philosophical and mathematical in character, and did not directly involve any experiments whatsoever. Begun in 1907, they culminated in 1911 with the enunciation of the celebrated "principle of equivalence", which has been stated and restated in many different ways. As actually used by Einstein in his mathematical calculations, however, this principle may be stated as:

> The effect of gravitation upon ideal "clocks" and "measuring-rods" at rest at a given point in a gravitational field is identically the same as that caused by a motion of the "clock" and "rod" through free space with a velocity equal to that which they would have acquired had they fallen, under the action of gravitation, from infinity to that point.

And these effects can, under the theory of relativity, be calculated by the Lorentz formulas. Thus, an ideal clock, at rest in a gravitational field, will run more slowly than a similar clock at rest in free space, for it is a basic tenet of relativity that a clock in motion in free space "goes more slowly than when at rest". Einstein, himself, states this new assumption, or principle of relativity as meaning that:[3]

> "The clock goes more slowly if set up in the neighborhood of ponderable masses."

And it is from this assumed behavior of "clocks" in a gravitational field that Einstein deduced his formula for the shift in spectral lines and the 1911 value for the deflection of light.

The cardinal principle of relativity is that the measured velocity of light is a fundamental constant of nature. This measured velocity depends not only upon the actual speed of light through space, but also upon the units of space and time in which the measurement is made. If the unit of time be lengthened, then, if

[3] EINSTEIN: "Die Grundlage der allgemeinen Relativitätstheorie," Annalen der Physik, 49: 1916, page 820.

the measured velocity is to remain constant, the actual speed of the ray in and through space must be decreased in like proportion. The velocity of light is 186,000 miles per second, and if this same velocity be measured by a clock "running slow", then in each of the longer seconds of the new clock light would travel more than 186,000 miles:—the measured velocity per second would be different and the cardinal principle of relativity would be violated. This can be adjusted, and the velocity, as measured in the new unit, be maintained at 186,000 miles only by an equal slowing down in the actual speed of the ray itself. Thus Einstein's new principle of equivalence, combined with the cardinal precept of relativity, necessitates the abandonment of the hitherto accepted principle that the actual velocity of light in space is constant, and forces the adoption of the assumption that the actual velocity of the ray through space decreases as it approaches the sun, or other gravitational body. Einstein alludes to this complete change in the fundamental concept regarding the propagation of light through space as:[4]

> "The principle of the constancy of the velocity of light holds good according to this theory in a different form from that which usually underlies the ordinary theory of relativity."

In accordance with this assumption, or new tenet of relativity, all rays of light, which pass through a given point in space, and regardless of the direction of propagation, will have the same velocity, and that velocity will become less and less as the point nears the sun, or other gravitational body. Thus a ray, proceeding directly towards the sun, will be retarded, not accelerated, as would be a falling body; and Einstein's new assumption, therefore, is that light is *repulsed*, or *repelled* by the sun.

The amount of this retardation must be exactly proportional to the slowing down of the ideal clock, as given by the principle of equivalence. At any point in space the square of the "velocity from infinity", under the Newtonian law of gravitation, is $2m/r$, where m is the gravitational mass of the sun. And in accordance with the Lorentz formula a "clock" moving with any velocity v

[4] EINSTEIN: "Uber den Einfluss der Schwerkraft auf die Ausbreitung des Lichtes." Annalen der Physik, 35: 1911, page 906.

is slowed down by the proportionate amount $1/2\ v^2/c^2$, where c is the velocity of light; so that a clock, moving with the "velocity from infinity", would be slowed down by m/rc^2; and the light ray must be slowed down in like proportion. The factor m/r is the well-known Newtonian potential; and making use of this symbol, Einstein writes his formula for the speed of light at any point in the gravitational field of the sun, as:[5]

$$c = c_0\left(1+\frac{\Phi}{c^2}\right)$$

where c is the velocity of light at an infinite distance from the sun, and Φ is "the (negative) gravitational potential". As the value of the potential function increases, the speed of the ray decreases; and thus this basic formula of relativity indicates clearly that light is retarded by gravitational action.

From this formula for an assumed, or hypothetical, change in speed, Einstein deduced his value for the bending of a ray of light as it passes near the edge of the sun. In doing this, he made use of the ordinary differential formula of physical optics, which expresses the rotation of the wave-front in terms of the change in velocity along the front. The entire shift in the direction of the wave as it passes any fixed point, or origin of coordinates may be obtained by integrating this fundamental formula between the limits of minus and plus infinity. Thus one has for the mathematical expression for the entire bending of the ray:

$$B = \frac{1}{c}\int_{-\infty}^{+\infty}\frac{\delta c}{\delta x}\,dy$$

The meaning of this formula is readily understood by reference to the diagram (Fig. 1), which is similar to one used by Einstein. The beam of light starts at A and travels towards B in a direction parallel to the axis of Y, and passes the origin of coordinates at the distance Δ. If the speed of different portions of the beam remain the same, then the factor $\delta c/\delta x$ is zero, and the path of the beam

[5] EINSTEIN: Loc. cit. page 906.

will be a straight line. But, if through any cause whatsoever the relative velocities of the inner and outer portions of the beam change, then the ray will be deflected from this straight and narrow path; and the above formula gives the entire deflection from the instant the ray started at A until it vanishes into space in the direction of B. The amount of this deflection depends upon the factor $\delta c/\delta x$, which represents the variation in the speed of various portions of the wave-front; it does not depend upon the cause of

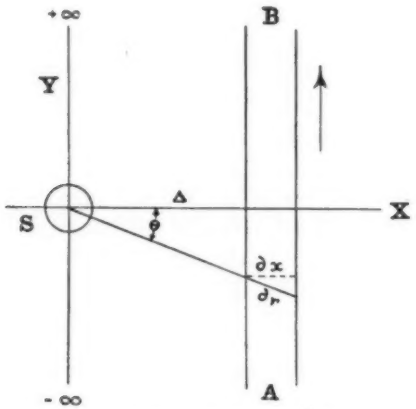


Fig. 1. The Deflection of Light.

such differences in speed. Such differences might be caused by the inner portion of the beam passing through a denser medium than the outer. This is the case of ordinary astronomical refraction: and this formula is used daily to compute the apparent change in the direction of a star, due to the passage of light through the earth's atmosphere.

Einstein used this simple formula of wave motion, and inserted in it his theoretical change in the speed of the wave as it passes through the gravitational field. This hypothetical change, as found from his speed formula, depends solely upon the varying value of the gravitational potential. And as this potential is a simple function of the distance of the wave at any instant from the sun,

the formula may be greatly simplified and the integration readily effected by replacing the rectangular coordinates, x and y, by their equivalents in terms of the polar coordinates, r and θ. When this is done and the proper numerical values of the factors are introduced, the total deflection of a ray, passing near the edge of the sun, is found to be:

$$0''.83$$

Now it must be borne in mind that this computation is one of simple mathematics, that the fundamental formula is one of ordinary physical optics and does not involve any curvature of space, or non-Euclidean geometry. The predicted relativity "bending of star light" thus depends upon the truth of the wave theory of light, and upon an assumption that gravitation decreases, or retards, the actual speed of the wave in and through space. The particular value, 0".83, of the 1911 prediction depends solely upon the special numerical assumption as to the rate of decrease in the speed of the wave as it approaches the sun.

In 1916 Einstein collected his various independent researches and wove them into the "General Theory of Relativity"; and, in so doing, was obliged to change his formula for the propagation of light in and through a gravitational field. The principle of equivalence, which had theretofore been applied solely to changes in clock rates, was now seen to be equally valid for changes in the lengths of measuring-rods. As such rods when in motion shrink, in accordance with the fundamental concepts of relativity, solely in the direction of motion, so this new development assumed that a measuring-rod, when placed radially in a gravitational field, would be shortened by a definite amount, but would retain its unchanged length, when in the tangential position. And this new development, in order to maintain the cardinal precept of relativity as to the measured velocity of light, involved and necessitated the corresponding assumption that a ray of light, proceeding radially, will be slowed down. But a ray of light passing tangentially through the gravitational field will have the velocity prescribed by the 1911 formula. Thus in the General Theory, as announced in 1916, the actual velocity of a ray of light, passing through a given point in a gravitational field, depends upon the direction in which it is mov-

ing:—the ray will travel faster when moving transversely, than when travelling directly towards or away from the sun.

The amount of this new radial retardation in the speed of light must be exactly proportional to the shrinkage in the length of the ideal measuring-rod, as given by the principle of equivalence. This shrinkage at any point in the gravitational field is determined by the "velocity from infinity" used in connection with the Lorentz formula. And these formulas readily give this radial shrinkage as m/rc^2, or in terms of the Newtonian potential, Φ/c^2. For a ray proceeding diagonally through the gravitational field, this new retardation will be similarly found from the component of the "velocity from infinity" in that direction. And this retardation becomes less and less as the ray becomes more nearly tangential, vanishing entirely for transverse ways.

The total amount by which a ray will be slowed down at a given point in a gravitational field thus depends upon two factors:—one a general slowing down of the ray, due solely to the gravitational effect upon "clocks"; the other, varying with direction, due to the effect upon "measuring-rods". Einstein united these two effects in a single formula, and gave the velocity of a ray of light, proceeding in any direction in a gravitational field, as:[6]

$$\gamma = \frac{c}{c_0} = 1 + \frac{\Phi}{c^2}\left[1 + sin^2\theta\right]$$

where θ is the angle between the radius-vector at any point on the path of the ray and the normal, drawn from the sun to the path. And this formula differs from that of 1911 solely by the addition of the term depending upon the direction in which the ray is propagated.

Now in revising his prediction as to the deflection of light by the sun to accord with this new development, Einstein used the same simple formula of physical optics, which he had used in 1911. In this formula he merely inserted the new value for the theoretical

[6] EINSTEIN: "Die Grundlage der allgemeinen Relativitätstheorie," Annalen der Physik, 49: 1916, page 822.

Einstein's notation has here been changed to conform to that used in his earlier papers; so that the 1911 and 1916 formulas can be directly compared.

variation in the velocity along the wave-front; so that the whole computation of 1916 involves nothing but a simple formula of physical optics and an assumed, or hypothetical, change in the speed

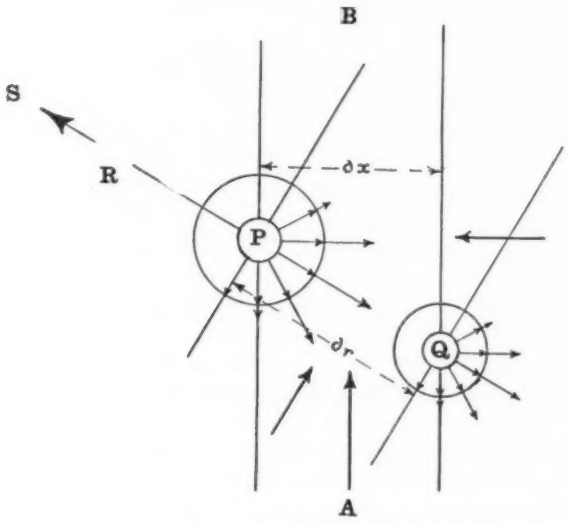


Fig. 2. EINSTEIN: Retardation of Light.

The 1911 assumption is represented by the arrows within the circles at P and Q, drawn contrary to the direction of the ray. The retardation depends solely upon the distance from the sun, being independent of direction, and is the same for rays not shown. The retardation at P is greater than that at Q.

The 1916 assumption is represented by the longer arrows extending beyond the circles. The additional retardation depends upon the direction in which the ray is travelling, being equal to the 1911 general retardation for radial rays and zero for transverse rays.

Einstein's Error. The essential factor for calculating the deflection of any ray is the difference in the lengths of corresponding arrows at P and Q. In his calculation Einstein used the difference in the lengths of radial arrows at P and Q instead of the difference corresponding to the path of the ray, which travels from A towards B.

of light as it passes through a gravitational field. In these formulas, and in Einstein's computation, there is not the slightest trace of non-Euclidean geometry, nor of "curvature of space". Unfortunately Einstein does not give the numerical calculation in detail: he gives merely the formulas and the result, stating that by carrying out the calculation:[7]

> "According to this, a ray of light going past the sun undergoes a deflection of 1".70."

This is exactly double the value given in 1911, and this doubling of values has given rise to many speculations, and to many and varied explanations, on the part of the relativists.

An inspection of the formulas, which Einstein used, shows exactly what he did and how he derived this result. The essential factor in the formula is that for the rate of change of velocity along the wave-front $\delta c/\delta x$; and this is the only factor in which any change can be made. All the other terms and factors of the formula are always identically the same. But, according to specific statements and to the speed formula, the value of this essential factor for a transverse ray, at its nearest approach to the sun, is identically the same in the 1916 theory as in that of 1911, but its value for a ray passing through the same point and proceeding directly towards the sun is, in the 1916 theory, just double that amount. Einstein used in his calculation the value of this factor for a radial ray, not that of a transverse ray; and thus introduced the mysterious factor two (2). This, of course, was a plain, straight mathematical error:—the rate of variation in the speed of a radial ray has not the slightest thing to do with the "bending" of a transverse ray.

Nor would it be mathematically correct to use, in this computation, the special value of this factor for a transverse ray at its closest approach to the sun, or the value of a transverse ray at any point. The use of such values would give identically the same result as did the 1911 theory, namely 0".83 for the total bending. For as the ray approaches the sun from a distant star, it is neither radial, nor transverse:—at a great distance from the sun it is very nearly radial; at its closest approach it is exactly transverse. Hence the value of this essential factor $\delta c/\delta x$ in the calculation will never be equal to that used by Einstein in 1916, and will always (except at the moment of closest approach) be greater than that used in 1911. But, as the greater portion of the "bending" occurs in the central portion of the ray's path, the total deflection will be much nearer the 1911 value than to the 1916 erroneous calculation. If

[7] EINSTEIN: Loc. cit. page 822.

the correct value of this essential factor for this varying ray be used in the formula, and the result be integrated in the usual way, one will then obtain for the full deflection according to Einstein's assumptions and basic formulas:

$$1''.10$$

and not the 1".70 of Einstein's paper.

All of this may be checked and confirmed by the work of Eddington as given in his famous "Report" to "The Physical Society of London". He used a different notation, but his formula for the velocity of a light-ray in a gravitational field is identical with that of Einstein. That this basic formula of relativity indicates a difference in the velocities of radial and transverse rays is made specific by the statement[8]

"The velocity thus depends upon direction."

Before computing the deflection of a ray of light by the gravitational action of the sun, however, Eddington makes a change in this speed formula. Upon the plea that it is[8]

"inconvenient to have the velocity of light varying with direction"

he shifts his origin of coordinates, or point of measurement for r, from the fixed centre of the sun to a moving point, which travels on the circumference of a small circle about the sun's centre. That is, he finds that by using an approximate and variable value of r for measuring the velocity of the ray at various points in the gravitational field, it is possible to so transform Einstein's formula as to make the velocity appear the same in all directions; to make the radial and transverse velocities the same function of the different and variable r's. But this is merely a mathematical trick of using a shifting origin, of measuring velocities of different rays from different points and in terms of different coordinates.

With this new formula the retardation of the ray, due to the gravitational action of the sun, appears as $2m/rc^2$, or exactly twice that of the 1911 theory. Neglecting the fact that he had "slightly" altered the coordinates, Eddington proceeded to use this expression for the retardation in identically the same way that the 1911 expression was used, and, of course, obtained a result just twice as

[8]Eddington: "Report on the Relativity Theory of Gravitation," 1918, page 53.

great, namely 1".70. But this result, so obtained, does not represent the curvature of the actual path of the ray by the sun; it represents a fictitious curvature as measured from a moving origin of coordinates. Eddington's result is neither mathematically correct,

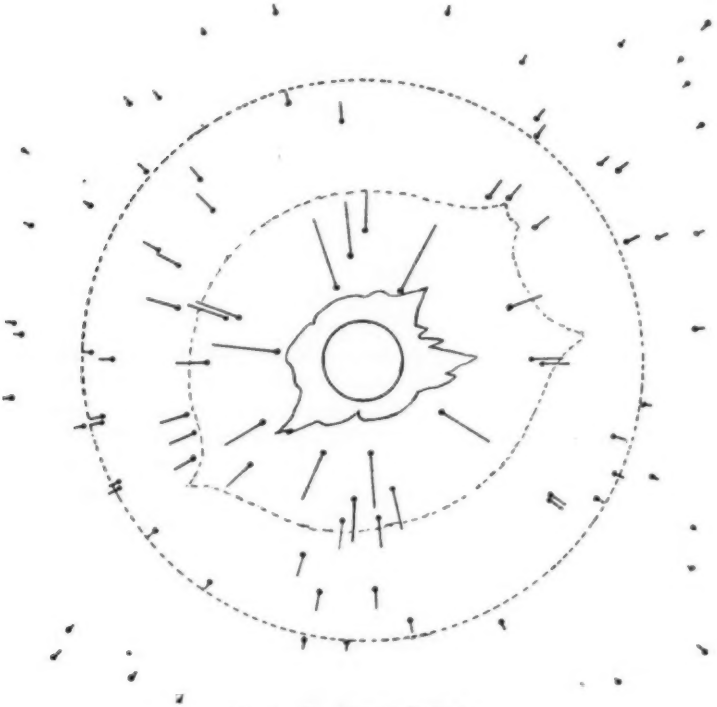


Fig. 3. The Einstein Prediction.

This figure shows the displacements, according to the prediction of Einstein, of the 92 stars observed by Campbell and Trumpler. These theoretical displacements are not the full predicted star displacements, but are the relative displacements derived from them, by Campbell and Trumpler, by applying the scale correction used in their Star Chart.

nor in accord with the basic assumptions of relativity in regard to the propagation of light. If Einstein's assumptions be correct, that the actual velocities of rays passing through a given point in space are different, if it be true, as both Einstein and Eddington state,

that the actual velocity of a radial ray at any point is less than that of a transverse ray, passing through that point, then by no trick of changing origins of coordinates, by no possible mathe-

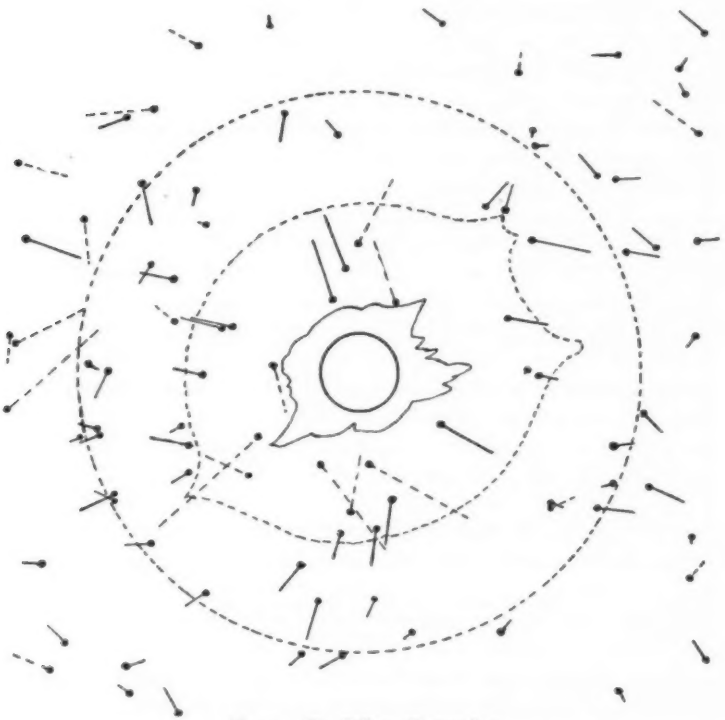


Fig. 4. The Eclipse Observations.

This figure shows the relative displacements of 92 stars as observed by Campbell and Trumpler at the total solar eclipse of September 21, 1922, and is from a direct tracing of the Star Chart in Lick Observatory Bulletin, No. 346. In that chart, however, the displacements of 21 stars were omitted: these have been added to make the above diagram complete and are shown by dotted lines.

matical means, can these two different velocities be made the same.

From all this it would appear to be clear that Einstein made an error in mathematical computation, when in his "Foundation of the General Theory of Relativity" he gave the figure 1".70 for the

theoretical relativity bending of light-rays by the sun. In accordance with his own assumptions and fundamental formulas this figure cannot be over 1″.10. The discordant and often elusive photographs of the various eclipse expeditions have shown, according to the published reports, a light deflection, varying between 1″.61 and 1″.98 for the 1919 eclipse, and between 1″.41 and 2″.16 for the 1922 eclipse; Campbell's result being first reported as 1″.72, but afterwards modified by the use of corrected data and made 2″.05[9]. If these observations represent actual deflections of light, then some cause other than the Einstein theory of relativity must be called upon to account for them.

In considering the results of these various expeditions it must also be remembered that no checks or controls were applied to determine either the cause of the observed stellar displacements, or even the point in space where the apparent bending occurred. No evidence has been given to show that the rays were bent in the vicinity of the sun: the observed effects may have been entirely local and due to abnormal conditions in the earth's atmosphere caused by the passage of the eclipse shadow. Simple and effective checks for the elimination of the effects, due to such possible causes, were available, but were not used.

It would thus seem that the general conception regarding Einstein's theory of light deflection is not in accord with the facts. In his actual formulas there is no trace of non-Euclidean geometry, or "curvature of space", nor do these formulas involve, or depend upon any "new" law of gravitation. The truth or falsity of the Newtonian law is not involved in his concepts, formulas, or predictions. The changed prediction of 1916 was due to the adoption of a new or revised formula for the hypothetical "retardation" of light in its passage through a gravitational field.

It would seem further that Einstein made a mathematical error in the practical application of his formulas to the eclipse problem: an error so large as to destroy the "confirmation" by the various eclipse expeditions.

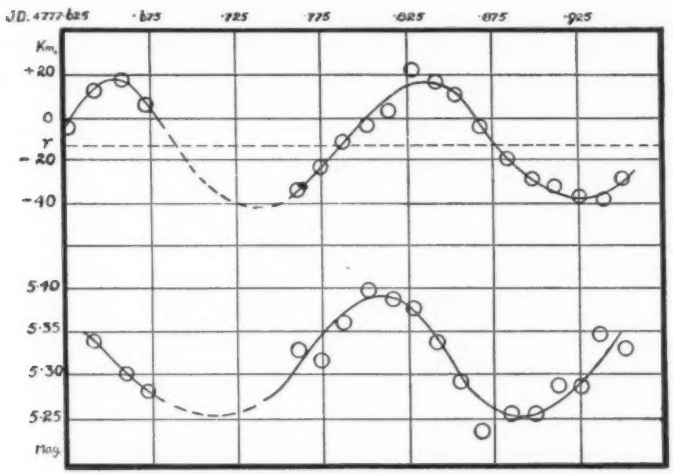
New York City, December 15, 1926.

[9] CAMPBELL AND TRUMPLER: "Lick Observatory Bulletin, No. 346," page 54.

VELOCITY AND LIGHT CURVES OF 12 LACERTAE

By William H. Christie

During the latter part of the summer of 1926 the writer was able to obtain simultaneous velocity and light curves of that interesting star, 12 Lacertae. This note is to give some idea of the



Velocity and Light Curves of 1R Lacertae
Sept 19, 1926

relationship existing between the two curves; a complete discussion of them will appear later in the "Publications of the Dominion Astrophysical Observatory."

The light curves were obtained by photographing the star with a camera strapped to the tube of the 72-inch telescope. This camera consisted of a wooden box in which was mounted an old Ross lens of 1¼ inch aperture and 24 inches focal length. The lens was so adjusted that extra-focal images about 1/50 inch in diameter were obtained on the 4 × 4 plates used.

An exposure of 20 minutes was required to give good images, so the spectra were made longer than usual, and the slit of the spectroscope was narrowed slightly, in order to lengthen the exposure time of the spectrograms to that of the direct photographs.

The extra-focal images were measured on the micro-photometer and the stars 8 and 10 Lacertae used as comparison stars. These stars are within a degree of arc of the variable, and are of magnitudes 5.38 and 4.91 respectively, according to the H.R.P., the mean value of 12 Lacertae lying between them.

The light curve obtained is highly satisfactory when we consider the method used to obtain it. Only one series of measures is given here, and in this the amplitude of the velocity curve, and perhaps the light curve, is near its maximum value. These values are plotted in the accompanying graph.

Julian Day	Vel.	Mag.	J.D.	Vel.	Mag.
4777.628	—32	—	4777.842	+17.7	5.33
.642	+12.6	5.34	.856	+11.6	5.29
.656	+18.0	5.30	.869	— 6.1	5.23
.669	+ 5.1	5.28	.884	—19.4	5.26
.758	—35.0	5.33	.899	—27.4	5.26
.772	—22.8	5.32	.911	—30.6	5.29
.786	—11.4	5.36	.925	—37.5	5.29
.800	— 4.8	5.40	.939	—28.5	5.35
.814	+ 2.9	5.38	.953	—28.6	5.33
.828	+23.1	5.37			

In conclusion, the writer wishes to express his thanks to the director, Dr. J. S. Plaskett, whose kindness made this investigation possible, and also to Dr. Baade for his valuable suggestions with respect to extra-focal image work given me during a visit to the observatory.

Ottawa, Ont.
June, 1927.

THE PLANET SATURN

A Concise Tabulation of Many Items of Interest to the Amateur

By W. G. Colgrove

Name—Saturn was the name of an ancient mythical Roman king, who reigned during the Golden Age. His name means sower, and he presided over the sowing of seed. His annual festival was held on the 17th day of December, shortly after the winter sowing. He has been carelessly identified with Chronos, the god of time, among the Greeks.

Myth—Saturn and Rhea his wife were two of the Titans, and were the parents of Jupiter. Milton tells how Saturn drove Ophion, the great serpent, and his wife Eurynome from the throne on Mount Olympus and became the ruler of the gods in his place. Huygens, the great astronomer, evidently forgot that Saturn was a Titan when he named the largest satellite Titan.

Symbol—A sickle corresponding to the scythe of Father Time, and this because Saturn was the slowest moving planet known to the ancients.

Sound—According to the fantastic notions of the ancient poets and philosophers, Saturn was assigned the rôle of deep bass.

Colour—Saturn is a dull yellow, increasing or decreasing in intensity in proportion to its distance and the aspect of its rings.

Form—This planet is unique among the planets, and is the most interesting member of the Solar System. There is the great central globe surrounded at the equator by a series of three flat concentric rings, outside of which revolve ten satellites.

Markings—The globe is banded above and below the equator; the rings present a gradation of colours and densities, and the satellites show some unusual peculiarities. The bands undergo a variety of changes during the year. Spots on the surface are seldom observed.

Stellar Magnitude—At mean distance it is of the first magni-

tude, which, like the colour, increases or decreases according to the distance and the aspect of the rings.

Angular Diameter—20″, 17″, 14″ of arc, being the greatest, mean and least. These and most of the following measures do not include the rings.

Linear Diameter—Polar 69,700, mean 72,350, equatorial 75,000 miles. This is computed from the apparent angular measurement above.

Circumference—Mean 227,400 miles. This is computed from the mean diameter and is nearly equal to the distance from earth to moon.

Area of Surface—About 16,700,000,000 square miles, or nearly 85 times our earth and .0071 of the sun.

Volume—About 230,000,000,000,000 cubic miles, or 765 times our earth and .00069 of the sun.

Mass—95.2 times our earth and .000286 of the sun

Density—.72 of water, or .13 of our earth and 1.39 of the sun. This would indicate that Saturn is still largely gaseous and a sphere of intense chemical activity.

Gravity—1.18 of earth—nearly the same. When we consider the volume, mass, density, and gravity together with the equatorial velocity we are amazed at the remarkable conditions on this world.

Rotation Period—10h. 14m. 23s. This was first determined accurately by Hall in 1876, through his observations of an unusual bright spot on the surface of the globe. There are therefore only about 5 hours daylight and 5 hours darkness, and also the remarkable number of slightly more than 25,000 days in a Saturnian year.

Equatorial Velocity—6.3 miles a sec., 23,000 miles an hr., 552,000 miles a day. This is about 4 times as fast as Mars, while its orbital velocity is only about .3 of Mars.

Polar Flattening—.11. This oblateness is the greatest of all the planets and is caused by the rapidity of rotation, which in turn causes an equatorial bulge amounting to about 6,700 miles.

Distance from Sun—841, 886, 931 millions of miles, being the perihelion, mean and aphelion distances respectively. It might be well to state here that the mean distance is one half of the major diameter of the planet's orbit.

Distance from Earth—744, 886, 1,028 millions of miles, being the distance at opposition, mean and conjunction respectively.

Diameter of Orbit—Mean 1,772,000,000 miles.

Revolution (Sidereal Period)—10,759.2 of our days, or 29.46 yrs. This is the time it takes to cover its orbit from a point in the zodiac back again to that point, as seen from the sun.

Revolution (Synodic Period)—377.5 of our days, this being the time it takes Saturn to pass from one conjunction or one opposition to the next.

Velocity in Orbit—6 miles a sec., 21,540 miles an hr., 516,960 miles a day. This is only a little less than its equatorial velocity.

Arc of Retrograde—6 degrees of arc. Planets retrograde, always westward, when nearest the earth; and advance, always eastward, when farther from us. At the points where they apparently change their direction they seem to stand still for some hours.

Eccentricity of Orbit—.056. This changes the planet's distance from the sun by about 90,000,000 miles between perihelion and aphelion. It also changes the orbital speed of the planet.

Light and Heat—.011 of what we get—that is, we receive about 90 times as much, but Saturn may be self-luminous on account of conditions previously mentioned.

Albedo—.6 about the same as Venus. This may not be entirely the result of its capacity to reflect but partly on account of a certain amount of its own radiation.

Temperature—Its own internal heat is probably its only source of the temperature apparent there. Being surrounded by a dense cloud envelope it can retain its own heat and also reflect the sun's light.

Atmosphere—The spectrum of Saturn's globe indicates a very dense and deep cloud-laden atmosphere. Its presence is also shown by the fact that when observing the disc or globe, the center is brighter than the circumference. The rings do not seem to have any.

Inclination of Axis to Orbit—63° 36′. Thus each pole and each side of the ring remain 14 years and 8 mos. in sunlight, and for a similar, alternate period in darkness.

Inclination of Equator to Orbit—26° 24′. This would produce marked seasonal changes, more pronounced than ours, and about 7 times as long. But since a gaseous condition still obtains, we cannot think of seasons in a terrestrial sense.

Inclination of Orbit to Ecliptic—2° 30′. The two points where the planet crosses the ecliptic from N to S and S to N are the nodes.

Phases—There are slight phases somewhat similar to those of Mars but greatly reduced because the breadth of the shaded area is only .5″.

Opposition—This is the position of a superior planet when our earth passes between it and the sun. Saturn's oppositions occur every year but with a delay of about 13 days. These are the best times for observation, especially if it is the time of year when the ecliptic is high in the evening sky.

Conjunction—This occurs at the opposite side of its orbit from the earth, and the planet seems to be lost for a time in the blinding rays of the sun.

Amateurs might profitably try foretelling elongations, quadratures, oppositions and conjunctions by plotting the orbit of the earth with the orbits of other planets and carefully measuring the angles and distances.

Satellites—Besides the regular type of satellite, Saturn possesses one of very peculiar contour. This takes the form of three almost concentric, flattened rings of great breadth which encircle the planet at its equator and revolve along with it. These were first seen by Galileo in 1610, but were not understood until 1655, when Huygens made his observations with better instruments. The outer diameter of the outside bright ring is about 172,600 miles and its breadth 11,060 miles. Then there is a space of some 2,300 miles, called Cassini's division. This is followed by another broader, brighter ring whose outer diameter is about 146,000 miles and its breadth 18,000 miles. Then, with a very slight division, comes a third but dusky ring discovered by Bond in 1850 and having an outer diameter of 110,000 miles and a breadth of 10,900 miles. The dark ring is like a veil through which, at times, the disk of the planet is discernible. The inner edge of this inner ring is about 6,000 miles

from the surface of Saturn. The thickness of the rings is small, less than 50 miles. In all probability they are composed of swarms of meteoric bodies revolving around their primary in individual orbits and in different periods, yet in each ring the particles are so nearly alike that they have become associated in the three distinct groups. During the past six years, on account of their inclination of about 27° to the plane of their orbit and about 28° to the plane of the ecliptic, these rings have been apparently opening out. In 1928 they will reach their widest, and then they will begin to close again, each process taking about seven years.

Saturn also possesses a brilliant family of 10 regular satellites. The first and largest, discovered by Huygens in 1655 and named Titan, is of the ninth magnitude; is at a mean distance of 771,000 miles; has a sidereal period of 15 dys. 22 hrs. 41 min. 23 sec.; a diameter of 3,000 miles and a mass of .00021 of Saturn. The last and smallest, discovered by W. H. Pickering in 1905 and called Themis, is of the seventeenth magnitude; is at a mean distance of 906,000 miles; has a sidereal period of 20 dys. 20 hrs. 24 min. The nearest called Mimas is only 117,000 miles distant; is of the fifteenth magnitude; has a diameter of 600 miles and revolves in about 22 hrs. 37 min. The farthest, Phoebe, is more than 8,000,000 miles away; is of the seventeenth magnitude; has a diameter of only 200 miles and revolves backwards in a period of 546 dys. The five nearest revolve in the same plane as their primary; the next two, Titan and Hyperion, are quite near this plane, but the others, excepting Phoebe, are inclined from 10 to 20 deg. These ten moons together have only six times the volume of ours, while all the light available from as many as shine at one time on Saturn is less than .01 of what we receive from our full moon.

Transits—Transits of the satellites across the disk of Saturn occur often, but are difficult to observe on account of their smallness and distance from us. Their shadows, however, can be seen on the face of the globe.

Life—From what has been said about the present conditions on Saturn it will be apparent that no life, as we know it, can exist there, so we must wait further development.

Lambeth, Ont.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

SIR ISAAC NEWTON'S BI-CENTENARY.

The History of Science Society, in collaboration with committees from the American Mathematical Society, Mathematical Association of America, American Astronomical Society and the American Physical Society, proposes to commemorate the 200th anniversary of the death of Sir Isaac Newton by an appropriate programme at Columbia University, New York, November 25 and 26, 1927.

On this occasion it is planned to have addresses relating to the great contributions of Newton to the advancement of mathematics, astronomy and physics, and setting forth his interests in chemistry, chronology, theology and other branches of learning. It is also hoped that some reference will be made to Newton's early contribution to the advancement of science in the American Colonies—when Harvard and Yale Colleges were in their infancy. Each subject will be represented by at least two papers given by scholars of distinction.

It is proposed to have a large exhibition of Newtoniana, including the first edition of the Principia, and other related publications, also portraits, medals and autographed letters and documents, and such material as bears directly upon his life, achievements and contemporaries. Therefore it is hoped that those who have material of this nature will take pleasure in loaning it to the committee in charge of the exhibit; it is requested that those who can contribute will communicate as soon as possible with the Secretary.

Similar commemorative programmes have already been held on the anniversary date of Newton's death, namely, March 20, by various societies and universities of this country, and also in England. The History of Science Society will take the opportunity to honor Newton, at its regular annual meeting.

A full programme of papers and speakers with other particulars will be published in "Science" during October.

The following individuals form the Programme Committee:

For the History of Science Society:—Dr. David Eugene Smith (Chairman), Columbia University; Dr. Henry Crew, Northwestern University.

For the American Mathematical Society, and Mathematical Association of America:—Dr. R. C. Archibald, Brown University; Dr. E. W. Brown, Yale University; Dr. Florian Cajori, University of California.

For the American Astronomical Society:—Dr. A. O. Leuschner, University of California; Dr. Frederick H. Seares, Mount Wilson Observatory.

For the American Physical Society:—Dr. Leigh Page, Yale University.

TENTATIVE DRAFT OF THE PROGRAMME

Columbia University, New York City, N.Y.—November 25 and 26, 1927.

November 25, 10.00 o'clock a.m.—Introductory address (Life of Newton), 30 min.; Mathematical papers, two, 30 min. each; Astronomical paper, one, 30 min. 2.00 o'clock p.m.—Physical papers, two, 30 min. each; Experimental physics, one, 30 min.; Astronomical paper, one, 30 min.

November 26, 10.00 o'clock a.m.—Miscellaneous papers, namely:—Newton and his Chemistry, 30 min.; Newton's Theological thoughts, 30 min.; Mint problems of Newton, 30 min.; Newton's first disciple in America, 30 min. 2.00 o'clock p.m.—Exhibition:—Books, first editions of Newton's works; Prints and photographs of Newton and his Contemporaries; Medals and Autograph letters and documents.

FREDERICK E. BRASCH, *Secretary of the Committee.*

Library of Congress, Washington, D.C.

MEETINGS OF THE SOCIETY

AT VICTORIA

October 12, 1926.—The meeting was called to order at 8.00 p.m. in the Physics Lecture Room at Victoria High School, with the President, Prof. Elliott, in the chair.

From the point of view of members, this meeting was the most successful in the history of the Society at this Centre. The audience of 300 included many of the Science students at Victoria College and Brantwood College.

The address of the evening was given by Dr. G. M. Shrum, of the University of British Columbia, on "Some Fundamental Concepts of the Atom." The lecture was illustrated by splendid lantern slides, and several simple experiments were performed by the speaker to demonstrate his points.

Dr. Shrum opened his address by dealing with some of the smallest particles of matter ordinarily known to man, and visible either to the naked eye or through the microscope. From these he proceeded into the realm of the invisible. It was shown that it was possible to count the number of molecules or atoms in a given body. The atom was itself composite in nature, being composed of protons and electrons. The electron, it was shown, could be separated from the atom. This was demonstrated in the conduction of electricity in a wire, the electron conducting the electricity. The X-ray, it was stated, was the result of the stopping of an electron. Numerous other examples of the same phenomenon were given, and Dr. Shrum asserted that it was possible to get even the size of these electrons and the number per atom. He stated that the electron was about one-two-thousandth smaller in mass than the lightest, or hydrogen, atom.

If one knew the number of electrons in an atom, one could get the number of possible elements. This number was ninety-two. It could also be shown that elements might have different masses but possess the same properties if they had the same number of electrons. There were many cases where an element existed with from two to three different masses but the same properties. These were called isotopes.

It was next demonstrated that by knowing the number of electrons associated with the atom, it was possible to determine how many possibilities there were for elements. Between hydrogen, the lightest element, and

uranium, the heaviest, there were ninety-two possibilities; and of these ninety-two, ninety were already known, four having been discovered in the last two years. Only two remain to be discovered, and there was a possibility that one of these would be brought to the knowledge of science in the near future.

In connection with this last reference, Dr. Shrum spoke of the fine research work which was being done in Canada, which had been very active in advancing a knowledge of physics and the construction of the atom.

Dr. Shrum then discussed the question of transmutation, showing the possibility of getting hydrogen from sodium, aluminium, magnesium, and other elements. But up to date science had no direct evidence of being able to make lead into gold, although radium is, in the course of time, transmuted into lead when left in a state of nature.

Pictures were thrown on the screen to illustrate transmutation; the knocking, for instance, of hydrogen out of nitrogen. Therefore, the lecturer added, all the atoms might be made up out of hydrogen.

The idea which the speaker emphasized at the close of his lecture was that science, by its increased knowledge of the atom, hoped in time to be able to give free release of atomic energy, which would be of great value to the world.

The lecture was brought to a close by a demonstration of the Shimizu experiment, which created much interest. After some lively discussion, a hearty vote of thanks was moved to the speaker by Dr. J. S. Plaskett.

November 16, 1926.—The meeting was at 8.00 p.m. in Victoria College, with the President, Prof. Elliott, in the chair.

The address of the evening was given by Prof. Buchanan, of the University of British Columbia, on "The Rejuvenation of the Stars."

Presenting the facts in a clear, non-technical language which kept his listeners interested throughout, and illustrating his points with the aid of a number of fine slides, Prof. Buchanan propounded the theory of Prof. Millikan of the University of Chicago on this subject.

At the beginning of his lecture Prof. Buchanan gave his audience an idea of the history of star-research, mentioning Herschel and several others of the earlier telescope gazers. Several slides of the Moon,—a dead world—and of nebulae and stars were shown and explained. The speaker dwelt at some length on sun-spots, and the condition of matter making up the sun. He also mentioned the method of discovering a star's composition by spectrum analysis. He then referred to the specifying of stars in group—O, B, A, F, G, K, M, N. They were classified by their decreasing surface temperature, he explained.

Approaching his subject of star rejuvenation, Prof. Buchanan propounded the Russell theory of star growth, in which nebulous masses, by contraction, became hotter, reaching a maximum of heat gradually to grow cold and become extinct.

The theory propounded by Prof. McMillan provided for the rejuvenation of these stars, he declared. When two bodies came into contact with the atmosphere, dead neutral particles, unaffected by gravitation, were thrown off into space, he explained. Prof. McMillan thought that by radiation of the stars these might become enlivened once again and form into nebulous masses. A star, when nearly extinct, coming into contact with such a nebulous mass, would absorb some of it, and thus, growing hotter, once more would ascend to the maximum as its density lessened, and it expanded. This was the rejuvenation process.

Taking the case of the solar system, Prof. Buchanan said that if the sun and the planets were to come into contact with such a nebulous system, Jupiter, the largest planet, would crowd Mars, Venus and the Earth into the sun, and would become by absorption of the nebulous matter a star, which with the sun would form a double star similar to many others in the universe.

Explaining the formation of star clusters and nebulae, Prof. Buchanan explained the McMillan theory in this manner: Attracted by the nebulous matter formed through the enlivening of dead particles by radiation, stars would travel at a rate of from 30 to 50 miles per second toward it, and some, when reaching the edge, would, as it were, from exhaustion, stop, while others would continue into the matter, and with others form a large cluster. This was, of course, all conjecture, he stated.

After discussion on the subject by a number of members, the meeting was brought to a close with a hearty vote of thanks to the speaker.

December 14, 1926.—*Annual Meeting*—The meeting was called to order at 8.15 p.m. in Victoria College; the President, Prof. P. H. Elliott, in the chair.

The annual reports of the Secretary-Treasurer were read, and on motion confirmed.

The President gave an interesting address, reviewing some of the principal scientific enquiries and achievements during the past year, especially, of course, in regard to Astronomy. He dealt principally with the newer theories of the structure and action of the atoms and electrons under varying conditions and circumstances.

The following were elected officers for 1927:—
Hon. Pres.—F. Napier-Denison.
President—Prof. P. H. Elliott.
Vice-Pres.—J. A. Pearce, M.A.
Sec.-Treas.—R. G. Miller.
Recorder—H. S. C. Archbold.
Council—Messrs. J. P. Hibben, E. E. Blackwood, H. H. Plaskett, Rev. J. C. Goodfellow, and the past Presidents.

January 25, 1927.—The Society met in Victoria College at 8.00 p.m., the Vice-President, J. A. Pearce, in the chair.

The following were elected members of the Society:—P. H. Keeling, North Lonsdale, B.C.; Alex. W. Bodley, 1525 Kingsway, New Westminster, B.C.; Rev. A. H. Priest, West Vancouver, B.C.; R. H. Spurway, Nelson, B.C. (A member of the Society on the roll of the Toronto Centre expressed his desire to affiliate with the Victoria Centre.)

Mr. H. H. Plaskett then took the chair, and called upon Mr. J. A. Pearce to address the Society upon the subject, "Some Unsolved Problems of the Solar System."

Introducing his remarks, the lecturer gave illustrations of the tendency of modern astronomers to devote their attention exclusively to the study of stellar problems, from which it is sometimes inferred that our knowledge of the solar system is practically complete. This, of course, is far from the truth, as every member of the system presents many unsolved, and, in some cases, practically unsolvable, problems.

The recent works of E. W. Brown and R. T. Innes, which go far to explain the anomalies in the motions of the moon and the inner planets, resulting from irregular changes in the rotation of the earth, due to actual variations in the size of the earth, were fully described.

The secular advance of the perihelion of Mercury, the long continued search for Vulcan, and the observations of Trumpler for intra-mercurial planets at the equiangular positions of Mercury and the sun were discussed.

Photographs of the planets were shown, and the difficulty of interpreting the surface markings, particularly of the Moon, Mars and Jupiter, were presented.

In conclusion, the dynamical theories of Sir George Darwin on the formation of the earth-moon system, and the theories of Chamberlin and Jeans on the origin of the solar system, were outlined.

The lecture was followed by much very interesting discussion.

February 22, 1927.—The Society met in Victoria College at 8.00 p.m., with the President in the chair.

The following new members were elected by the Society:—Mrs. Edith Murray Dow, R.R. 1, Kelowna, B.C.; Mr. T. L. Gillespie, East Kelowna, B.C.; Mr. H. S. C. Archbold, 1692 Earle St., Victoria, B.C.; Mr. Geo. A. Bucklin, 2275 Oak Bay Ave., Victoria, B.C.; Mr A. Waring Giles, Vernon, B.C. (A member of the Society at the Ottawa Centre desired to affiliate with the Victoria Centre.)

The address of the evening was given by Mr. H. H. Plaskett, on "The Nebulae."

After a brief historical survey of the early work on the nebulae, the lecture proper commenced with a summary of the principal facts known

about the nearer nebulae. Slides from recent beautiful Mt. Wilson photographs showed the three principal types, the bright diffuse nebulae, the dark diffuse nebulae, and the planetary nebulae. Then followed a brief account of the important empirical relations found by Major Edwin Hubble between the temperatures of the stars associated with their different types of nebulae and the kind of light the nebulae themselves emitted.

The second part of the lecture dealt with the theories of Zaustra and Eddington which have been proposed to account for these observed facts. Illustrations were given of the incredible tenuity of such nebulae, the density being such that a volume of 570,000 cubic miles of the Orion nebula would have a mass of only one ounce. It was then explained how the associated star excited the nebula to give forth its light, and various terrestrial analogies were cited.

Many of the audience took part in the interesting discussion which followed the lecture.

March 15, 1927.—The meeting was held in Victoria College, at 8.00 p.m., with the President in the chair.

The following were elected members of the Society:—Mrs. H. W. Herchmer, 605 Trutch St., Victoria, B.C.; R. W. Hunter, 2087 Crescent Rd., Victoria, B.C.; William Herbert Hall, Vernon, B.C.; Miss E. S. Gibson, Vernon, B.C.

The address of the evening was given by the Rev. John C. Goodfellow, on "Sir Isaac Newton, his life and work."

This subject was selected to commemorate the two-hundredth anniversary of the death of Sir Isaac Newton. This illustrious astronomer died on March 20th, 1727.

Beginning with Newton's birth at Woolsthorpe, Lincolnshire, in 1642, Mr. Goodfellow recalled some facts concerning the great scientist's early schooling, something about the family history, and about the political and theological background of his young manhood. It was shown that Newton, even in that time of great disturbance, went his own way practically uninfluenced by the happenings of the hour. Newton was admitted a member of Trinity College, Cambridge, in 1661, and was elected for a scholarship three years later. At an early age he began to make careful observations of natural phenomena, but science did not by any means occupy the whole of his time, for he was a member of Parliament for a time, and also became Master of the Mint.

Mr. Goodfellow discussed in some detail Newton's actual scientific work and the contribution which he had made to mechanics and astronomy, and also referred to the debt which Newton owed to men such as Copernicus and Galileo, who preceded him. Among the discoveries with which he should be credited are the method of infinitesimal calculus, in which he anticipated Leibnitz by some months.

In physics Sir Isaac would be best remembered perhaps for his analysis of light by the prism, which is so important in astronomical and other work to-day. Newton also constructed a small reflecting telescope, and the Royal Society, London, is in possession of this instrument to-day.

Not the least interesting part of the lecturer's story of Newton was that which dealt with the man himself as distinct from the scientist. In his relations with his fellow men, Newton had a very happy manner, and was extremely popular both with his students and his colleagues.

Among the interesting manuscripts which Newton left were some works on theology, one being on the "Prophecies of Daniel," and the "Apocalypse of St. John." Another was a "Church History, with a History of the Creation."

Newton was buried in Westminster Abbey.

April 5, 1927.—The meeting was called to order at 8.00 p.m. in Victoria College, with the President in the chair.

One new member was elected to the Society:—Mrs. L. K. Poyntz, 1348 Port St., Victoria, B.C.

The address of the evening was given by Dr. J. S. Plaskett, F.R.S., Director of the Dominion Astrophysical Observatory, on "Our Galaxy and Beyond."

In this the lecturer discussed the results attained by modern astronomers in determining the stupendous size of the universe, and establishing the existence of thousands of island universes, comparable in size with our universe, scattered throughout the depths of space.

Following the explanation of how interstellar distances are measured, the lecturer discussed the work of Shapley on globular clusters, which proved, among other things, that the diameter of the stellar universe is of the order of 30,000 light years (two million, million, million miles). The nebulae work of Hubble, which definitely settled the controversy over the nature of the spiral nebulae, was referred to.

Photographs were shown of such subjects as the mysterious Magellanic Clouds, N.G.C. 6822, the Great Andromeda nebula (50,000 light years in diameter), and the Spiral nebula (Messier 33, in the Constellation Triangulum).

The meeting was well attended, over 150 being present. Adjournment was at 9.45 p.m.

May 12, 1927.—The closing meeting for the session was held at the Dominion Astrophysical Observatory, Little Saanich Mountain, which was kindly opened to members of the society and their friends for that purpose on May 12, at 8.00 p.m.

It had been hoped that observations of the moon and stars would

occupy the evening, but at that time it was too cloudy to make any satisfactory observations. Members of the staff, however, voiced the opinion that later in the evening the clouds would thin out. Meantime the audience assembled in the dome of the observatory, where the work of the institution was briefly outlined, and the construction and operation of the dome and the huge telescope, as well as the instruments, were described in detail by Mr. J. A. Pearce. As Mr. Pearce spoke of the huge weights as compared with the delicate instruments, Mr. R. M. Petrie illustrated the speaker's description by showing how very easily and accurately they could be handled.

The meeting then adjourned downstairs, where Dr. J. S. Plaskett gave an interesting address, which was in the nature of an extension to his address of the meeting before. Dr. Plaskett expressed his gratitude at the interest shown in the institution and welcomed the members.

Dr. Plaskett's address was illustrated with a number of slides graphically depicting the remarkable range of astronomical research, the survey extending from the infinitely small electronic dimensions of the order of a millionth of an inch, to the figures of the Einstein Universe—nearly 480,000 million, million, million miles. These slides had been prepared specially for the occasion by the speaker, and were shown for the first time with a set of stereoscopic photographs of the moon, planets and comets.

A vote of thanks was tendered the speaker, and before the meeting adjourned three new members were elected to the society: viz.—Mr. E. Buckle, 3424 Saanich Rd., Victoria, B.C.; Mr. F. R. Liniehen, 423 Powell St., Victoria, B.C.; Mr. T. P. O. Menzies, Curator, Vancouver Museum, Vancouver, B.C.

As had been predicted by the staff, the sky had now cleared up sufficiently to make excellent observations of the moon, which appeared as a brilliantly white disc with pale clouds scudding across it. Several stars were also viewed by all present, through the 72-inch telescope.

When everybody had gazed at the heavens, the party left for the city, after having thoroughly enjoyed a very instructive evening.

H. S. C. Archbold, *Recorder.*

AT LONDON

The February meeting of the Society was held in the Normal School on Friday, February 18, 1927, at 8.15 p.m. Dr. Kingston presided. On motion of Messrs. White and Saunders, D. S. Ainslie, M.A., Ph.D., was made a member of the Society. On motion of Messrs. White and Bowen, Mrs. Geo. M. Reid was made a member.

Mr. E. H. McKone, B.A., B.Paed., gave an interesting address on Astrology. Two slides were used to show the Zodiacal Man and the Signs of the Zodiac. Attention was directed to the arrangement of the signs with reference to the parts of the body. It was pointed out that the

Astrologers believed that the seven planets (which include the Sun and the Moon) and the twelve signs of the Zodiac exercised a strong influence on human life. The particular arrangement of the planets and signs at the exact hour of the individual's birth determined his character and destiny. Mr. McKone stated several of the theories that have been advanced to account for the origin of Astrology and noted this fact, that these theories do not agree but contradict one another in many important particulars. The significance of the numbers twelve and seven were explained thus:—Three is the symbol of Divinity, and four is the symbol of humanity, three plus four or seven represents perfect humanity, and three times four or twelve represents the universe.

The importance attached to the planets can be seen in the names given to the seven days of the week. The position of Aries at the head of the man was explained by the fact that the ancients worshipped the sun, and the setting of the sun was attended by fear and foreboding, while the rising of the sun brought joy and gladness. The return of Spring with the promise of warmth was a time of feasting; 3000 years ago at the vernal equinox the sun was in Aries. The sun had overcome the ram and Aries became a sacrificial offering.

By means of excellent blackboard drawings Mr. McKone demonstrated some of the changes occasioned by the precession of the equinox. 3000 years ago at the vernal equinox the sun was in Aries, 5000 years ago it was in Taurus when Spring was ushered in, and at the present time the vernal equinox finds the sun in the constellation Pisces.

E. T. WHITE, *Sec. Treas.*

AT MONTREAL

The meeting was in the Macdonald Physics Building, February 17, 1927. The President, Col. W. E. Lyman, in the chair.

New members were elected as follows:—Miss Thibaudeau, Mr. Albert Morin, Mr. Louis Lefort, Mr. Jos. Fiset, C.S.C.

The lecturer was Professor A. H. S. Gillson, of McGill University, his subject being "The Earth."

The following topics were discussed in an interesting, popular, yet comprehensive manner: Proof of spheroidal shape of the earth (ellipticity 1/297.6); proof of diurnal rotation (Foucault's pendulum); mass and density of earth (Airy, Cavendish); calculations of Laplace, Sir George Darwin and Picart regarding behaviour when spinning of certain models representing approximately the earth; variability of gravity and theory of isostasy (Pratt, Helmertz, Hayford); tidal phenomena and elastic properties of earth (Kelvin, Darwin, Michelson and Gale); movement of pole and variation of latitude (Euler, Chandler, Newcomb); earthquake phenomena. fast longitudinal and slower transverse waves giving data regarding interior

structure of earth; recent model by Harold Jeffreys accords with both tidal and seismological facts (liquid metallic core of density 12.0 and radius 0.5 total radius, outer portion density 4.25 and twice the rigidity of steel); precession, known to Hipparchus, explained by Newton as gyroscopic phenomenon, the sun's pull on the earth's equatorial bulge producing precession of period 26,000 years; The Moon—its mass, density (0.75 earth's density) tidal effects; Tidal friction and its influence on length of day, in 5×10^{10} years the *day* and the *month* will coincide and will equal 47 days, solar tides will then retard earth until the day equals 7 months and moon will approach earth to a distance of twice earth's radius when tidal disruption of moon may occur; Resonance Theory of Origin of Moon, 10^9 years ago when earth was fluid, day was 4 hours and natural period of pulsation was 2 hours coinciding with solar tidal period (Darwin).

A vote of thanks was proposed by Dr. L. V. King and heartily carried by the large audience. Mr. Asbury solicited new members and the meeting adjourned.

March 18.—This being a joint meeting with the McGill Chapter of the Sigma Xi and the McGill Physical Society, the chair was taken by Dr. A. S. Eve, F.R.S., who introduced the speaker of the evening, Prof. A. H. S. Gillson, Isaac Newton Scholar of the University of Cambridge 1913–1916, whose address took the form of a Commemorative Lecture, March 20th being the 200th anniversary of the death of Sir Isaac Newton, Mathematician, Astronomer, Physicist.

The speaker outlined the development of mathematics up to the time of Newton, and then described Newton's contributions, Binomial Theorem, Differential and Integral Calculus, etc. His work on Optics was outlined, the invention of the Reflecting Telescope, the theory of colour, etc. The *Principia* was described, Book I containing the three laws of motion, the parallelogram of forces, Theory of Orbits and disturbing forces; Book II, on Hydrodynamics, waves, tides, velocity of sound in air, motion of a projectile in a resisting medium; Book III, applications of the above in Solar System, Angular rotation and polar flattening, lunar theory, tides high and low, mass of moon, precession of the equinoxes. At the age of 73 Newton solved the problem of orthogonal trajectories in five hours.

Amongst many tributes to the "tremendous, overwhelming greatness of Newton" is that of Lagrange, who wrote that the *Principia* was the greatest production of the human mind.

The lecturer closed by remarking that it was a disgrace to Englishmen that there is still no complete edition of Newton's works. Amongst the unpublished papers Adams and Stokes found a calculation of the angular rotation of the moon's orbit giving the value actually observed (3°) and amending an earlier computation which had given only half the true amount.

A vote of thanks was tendered by Prof. A. Willey, F.R.S., and carried unanimously.

A. Vibert Douglas, *Secretary*.

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